

ELECTRONIC FUNDAMENTALS

SERVICE PRACTICES 26

MICROPHONES AND LOUDSPEAKERS

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RCA INSTITUTES, INC.
A SERVICE OF RADIO CORPORATION OF AMERICA
HOME STUDY SCHOOL
350 West 4th Street, New York 14, N. Y.

Service Practices 26

INTRODUCTION

In this lesson, we take up the practical aspect of microphones and loudspeakers. We will consider microphone and loudspeaker ratings and how to use them to select the proper types for various purposes. We will go into the trouble-shooting and repair of loudspeakers.

26-1. MICROPHONE CHARACTERISTICS

Microphones have two characteristic electrical qualities — impedance and output level (sensitivity). Servicemen must understand these qualities in order to interpret technical data describing microphones.

Impedance. The electrical output impedance of a microphone changes with the sine-wave frequency of the output signal. When the output signal represents speech or music, it is a combination of many sine-wave frequencies, and the total output impedance is complex. Under operating conditions, the impedance varies continuously over a limited range of values.

It is important to have some way of specifying the impedance of a microphone because the traits of high-impedance microphones differ from the traits of low-impedance microphones. For this reason, microphones are rated according to the impedance at the output terminals when the microphone is delivering a 1,000 cps sine-wave signal. The rating is approximate. For example, if the actual impedance at 1,000 cps lies anywhere within the range 20,000 to 80,000 ohms, a microphone impedance is rated at 40,000 ohms, which is a typical high-impedance microphone rating. Typical low impedance microphone ratings are 50 ohms, 150 ohms, and 600 ohms.

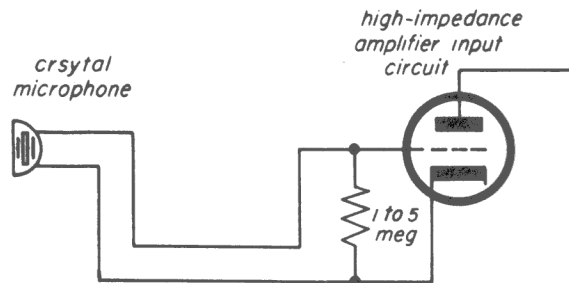


Fig. 26-1

The crystal microphone is by nature a high-impedance device. The output impedance of a crystal mike can be made low by placing a step-down transformer in the microphone assembly, but this is not done. So it is safe to assume that the output impedance of crystal microphones is high. Microphones that operate according to the magnetic-generator principle (dynamic mikes, velocity mikes, etc.) are, by nature, very low impedance devices. A step-up transformer is included in the assembly of such microphones, even those with a rated output impedance as low as 50 ohms. It is also common practice to design the step-up transformer to produce a high-rated output impedance (40,000 ohms). Carbon microphones have low-rated output impedances.

A significant difference between high and low impedance microphones is that different amplifier input circuits are required for each. High-impedance microphones can be directly connected to high impedance amplifier input circuits. High-impedance amplifier input circuits (Fig. 26-1) are the simplest and least expensive kind. One lead from the mike output terminals connects directly to the control grid of the amplifier. The other lead connects to the cathode. A grid resistor ranging in value from one to five megohms connects from grid to cathode. That is all there is to the circuit.

High microphone impedance has disadvantages. It limits the length of mike-to-

amplifier connecting cable usable without excessive signal loss in the cable, and it makes the cable susceptible to stray hum and noise pickup. Stray shunt capacity between the two conductors of the cable causes cable loss. The capacity has a capacitive reactance. This reactance is an impedance which, because it is in shunt with the mike output impedance, is in a position to load the mike and reduce its output. The same value of cable-shunt impedance can exert a greater shunting effect upon high-impedance microphones than upon low-impedance microphones. This is why low-impedance mikes are not troubled by cable loss.

To illustrate, assume that the reactive impedance of the cable is 40,000 ohms. This is an extremely low value, but will illustrate the effect. Such a cable in shunt with a 40,000-ohm (high impedance) mike will reduce the impedance across the microphone output terminals by roughly fifty percent of its unloaded value. The same 40,000-ohm cable reactance in shunt with a 500-ohm (low-impedance) mike will reduce the total impedance across the output terminals by only about twenty percent of its unloaded value. Actual values of shunt cable reactance are much higher than 40,000 ohms, so the output impedance of low-impedance microphones is reduced hardly at all.

Because the shunting effect of the cable is proportional to length, cable lengths used with high-impedance microphones should not be longer than twenty-five feet. This is a satisfactory length for most public-address installations and for radio-transmitter installations, such as amateur transmitters and communications transmitters, where the length of microphone cable can be short.

Note: It is important to know what kind of impedance is being talked about when you hear about microphone impedance. When servicemen speak about the impedance of microphone cables, they are not talking about the shunt reactive impedance described above. When they speak of a cable that has a high impedance, they mean a cable that is connected to a high-impedance microphone. The same cable would be said to have a low impedance if it were connected to a low impedance microphone. Used in this way, the

term *high-impedance cable* is meaningful. It reminds us that the cable is susceptible to stray pickup because of its high impedance level.

But, when we wish to state, for example, that such and such a microphone cable has a high shunt capacitive-reactance impedance (and therefore it is suitable for use with a crystal microphone), we say instead that the cable has a low shunt capacity (and therefore it is suitable for use with a crystal microphone).

Let's consider stray hum and noise pickup in more detail. When a cable is connected to the output terminals of a high-impedance microphone, the high output impedance of the microphone exists between the two wires of the cable at every point along the entire length of the cable. (Thus, the cable is said to have a high impedance.) Like any circuit at a high impedance level, the cable can pick up stray hum and noise voltages, which exist in space in the form of electrostatic fields. These fields are present almost everywhere, because the electrical power wiring and the electrical appliances that produce fields are present almost everywhere.

An electrostatic field is equivalent to a generator that delivers a small current (measured in microamperes). The alternating voltage field is electrically connected by capacitor action to all conducting surfaces that it surrounds. Even though the current is small, the field is able to impress a voltage that affects the operation of a high-impedance microphone and cable because a high impedance does not demand much current from the generator.

A low impedance demands more current. As a generator, the electrostatic field cannot deliver the current demanded by a low impedance. The consequent overload causes the generator's output voltage to drop, so a low impedance picks up less voltage from an electrostatic field than does a high impedance. High-impedance microphone cables are, in effect, two long wires with a high impedance between them. The fact that the wire terminations of this high impedance are long further increases the possibility of pick up from a static field, because the long

wires expose a large conducting surface to the field. In a way, this condition represents a good electrical connection at the terminals of the generator (the electrostatic field).

It is the magnitude of voltage picked up from static hum and noise fields that determines whether such stray pickup will be audible, just as it is the magnitude of voltage delivered by a microphone — not current or power — that determines how loud the resulting sound will be. This is because the microphone and its cable always connect to an audio voltage amplifier. No current flows in the grid circuit of these amplifiers, and no power is consumed. A given input voltage will result in a certain (larger) output voltage from the amplifier, regardless of the power or current delivering capability of the generator that is delivering the input voltage.

Output Level. There is a connection between microphone output impedance and microphone output level. The step-up transformer that is a part of magnetic microphone assemblies not only raises the naturally low impedance of these microphones to the desired rated output impedance, but it also raises the output voltage. (All step-up transformers work like this). The power output remains practically unchanged. The current decreases. However, it is the magnitude of the voltage that determines the kind of amplifier input circuit required for high- and low-impedance microphones. Figure 26-2a shows a high-impedance amplifier input circuit with a microphone with a high output impedance connected to it. It may be either a crystal mike or a high-impedance magnetic mike (or a condenser mike, a high-impedance mike not now in general use). Comparable output levels are delivered by magnetic and crystal high-impedance microphones.

Figure 26-2b shows a low-impedance amplifier input circuit properly connected to a low-impedance magnetic microphone. Magnetic microphones have two parts: the *transducer*, which changes sound to an electrical signal; and the step-up transformer, which raises both the natural impedance of the transducer and the voltage level of the signal generated in the transducer.

The transducers in Fig. 26-2a and b are identical. The only difference between the

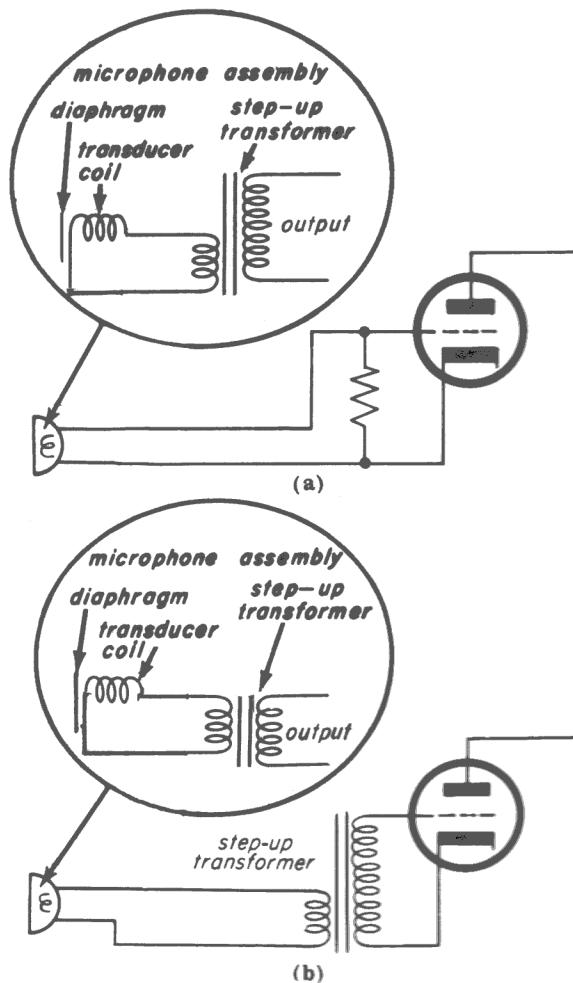


Fig. 26-2

two mikes is that the transformer at *a* steps up the impedance and the output signal voltage more than does that at *b*. The low-impedance magnetic mike *b* has less output-signal voltage than the high-impedance magnetic mike *a*. So a step-up transformer is found at the input of the amplifier used with the low-impedance mike to step up the signal to roughly the same voltage at the amplifier grid as the signal delivered by the high-impedance mike. If both amplifiers have the same gain from grid to plate, their signal outputs will have the same magnitude. Therefore:

1. We may expect that low-impedance microphones will have a lower output voltage level than high-impedance microphones.
2. We may expect to find a step-up transformer at the input of an amplifier intended to be used with low-impedance microphones.
3. We may expect to find the same number of voltage-amplifier stages (tubes) in an am-

plifier delivering a certain output, regardless of whether the input is arranged to receive a high-impedance or a low-impedance mike. The additional voltage gain (step-up) that is necessary for low-impedance microphones is provided by the transformer at the amplifier input.

These conclusions apply to ordinary high-impedance crystal and magnetic mikes and to low-impedance magnetic mikes, but not to some rather special kinds of microphones, such as the condenser mike. Ordinary microphones are roughly alike in output delivering ability. In fact, there are differences in the exact rated output of the various ordinary mikes that are available, but the differences are not great enough to require another stage of amplification for mikes with lower output. Presently, we will take up microphone output-level ratings. These are given by microphone manufacturers to enable us to know microphone output voltages in exact terms. However, it is useful for practical purposes to know that a typical value of output signal voltage for the ordinary microphone operating under typical conditions is 0.005 volt *at the amplifier control grid*.

Before we take up the output rating systems, let us briefly consider the practical aspect of carbon microphones with regard to output level. The output level of carbon microphones is so high that one less stage of voltage amplification is needed for them compared to run-of-the-mill crystal and magnetic mikes. In practice, this means that a carbon microphone can be connected directly to the input of a home-radio type audio amplifier, and it will produce a satisfactory level of sound volume at the loudspeaker. Crystal and magnetic microphones require a one-tube preamplifier to work through a home-radio type audio amplifier.

The output rating of a microphone is given in decibels together with a statement of the strength of sound that produces it. This two-part rating statement is a measure of microphone sensitivity in the sense that it tells us how much output the mike will deliver for a certain strength of sound input. The strength of sound input is usually given in dynes per square centimeter, as described in Theory Lesson 26, and we will use this

form throughout, although the term microbar is also in use.

$$1 \text{ microbar} = 1 \text{ dyne/cm}^2$$

Many systems for rating microphone output are in use. As a result, some confusion exists. The following discussion and tables are based upon and used by permission of the *Radiotron Designer's Handbook*, edited by F. Langford-Smith. Both decibels of voltage and decibels of power are used to rate microphone output. Table A lists some of the ratings in common use.

It is proper to use decibels of power to rate magnetic microphones because magnetic microphones, by nature, are able to deliver a constant power to a wide range of matched load resistances. The voltage delivered changes with the value in ohms of the matched load. (If the load is connected in a way to mismatch the mike-output impedance, power no longer remains constant). Crystal and condenser microphones, on the other hand, deliver a constant voltage over a limited range of load resistance, while the power output varies with load resistance. The voltage referred to here is the nominal voltage output from a crystal mike, which is measured at a frequency midway in the audio range. Voltage output from a crystal mike at lower audio frequencies decreases more rapidly with decreased load resistance, and this property is taken advantage of for equalizing purposes. No impedance matching is involved, since matching is a device to insure maximum transfer of power, not voltage. Power decibels are not used to rate crystal and condenser microphones.

When a magnetic microphone's output level is rated in decibels of power, the rating holds true regardless of the value in ohms of the load into which the microphone works, as long as the load is matched to the microphones. To be matched, a microphone must be terminated in an impedance equal to its rated output impedance, either directly or through a matching transformer. Identical magnetic transducers may be contained in several microphone assemblies, each with a different step-up transformer and, consequently, each with a different output impedance. The decibel power output of

these several microphones will be identical. Power output is determined by the power developing capability of the transducer. The five decibel output rating systems labeled E, F, G, H and J in Table A are power output ratings. They are used mostly to rate low-impedance magnetic microphones. The terms of one system may be converted to terms in another system by the addition or subtraction of the decibel correction factors

shown in Table B. This procedure is useful when it is necessary to compare the output delivering ability of two mikes, each of which is rated differently.

Any of the five power statements may be converted to a voltage statement. But then the voltage statement holds for only one value of rated output impedance. When the decibel part of one of the five power ratings

TABLE A

Voltage Ratings	
A.	Open-circuit voltage output in decibels to the one-volt reference level (0 db = 1v), expressed in dbv, for a sound input of 1 dyne/cm ² . This is a crystal-microphone rating.
B.	Open-circuit voltage output in decibels to the one-volt reference level (0 db = 1v), expressed in dbv, for a sound input of 10 dyne/cm ² . This is a crystal-microphone rating.
C.	Volume-units output (as read from a vu meter), expressed in vu, for a sound input of 10 dyne/cm ² . This is a way of measuring microphone output rather than rating output.
D.	High-impedance grid voltage in decibels to the one-volt reference (0 db = 1v), expressed in dbv, across a resistance of 40,000 ohms for a sound input of 1 dyne/cm ² . This is a high-impedance magnetic microphone rating. All the other ratings can be converted to this form.
Power Ratings	
E.	Power output in decibels to the one-milliwatt reference level (0 db = 1mw), expressed in dbm, for a sound input of dyne/cm ² . This is a modern low impedance microphone rating.
F.	Power output in decibels to the one-milliwatt reference level (0 db = 1 mw), expressed in dbm, for a sound input of 10 dyne/cm ² . This is a modern low-impedance microphone rating.
G.	Power output in decibels to the six-milliwatt reference level (0 db = 6 mw), expressed in db, for a sound input of 1 dyne/cm ² . This is an older form of low-impedance microphone rating.
H.	Power output in decibels to the six-milliwatt reference level (0 db = 6 mw), expressed in db, for a sound input of 10 dyne/cm ² . This is an older form of low impedance microphone rating.
J.	Power output in decibels to the one-milliwatt reference level (0 db = 1 mw), expressed in db, for a sound input of 0.0002 dyne/cm ² . This is the Radio Manufacturers' Association Microphone System Rating (R.M.A. Standard SE-105).

TABLE B

To Convert	Add db
E to F	+ 20
E to G	- 8
E to H	+ 12
E to J	- 74
F to E	- 20
F to G	- 28
F to H	- 8
F to J	- 94
G to E	+ 8
G to F	+ 28
G to H	+ 20
G to J	- 66
H to E	- 12
H to F	+ 8
H to G	- 20
H to J	- 86
J to E	+ 74
J to F	+ 94
J to G	+ 66
J to H	+ 86

is in dbm (0 db = 1 mw), it can be converted to a decibel statement of voltage output with reference to one volt (0 db = 1 v) by adding or subtracting one of the values of decibel correction factor listed in Table C. The matched load impedance across which this decibel voltage output will develop is the

impedance (Z) in Table C corresponding to the correction factor (C.F.) that is employed. The sound input part of the rating remains unchanged.

Low-impedance magnetic microphones are occasionally rated in terms of voltage-decibel statements of the kind that result from converting power statements with the aid of Table C. Such ratings are true (power) decibels because the resistance factor (impedance) is given. The voltage rating holds true for only the given impedance. High-impedance magnetic microphones are usually rated in the system labeled D in Table A. This rating system states true decibels of voltage output across 40,000 ohms. Let's call rating D the *high-impedance grid-voltage rating*. In addition to being the form most used to rate high-impedance magnetic microphones, it is useful as a standard of comparison because all the five power ratings can be converted to it. Also, it is the only magnetic microphone rating that comes close to corresponding to crystal microphone output ratings (A and B of Table A). When conversion is made by means of Table C from the rating of a low-impedance microphone to the high-impedance grid rating, it gives the voltage in decibels at the grid of the amplifier. This can be understood with the aid of Fig. 26-3. Fig. 26-3a shows a low-impedance magnetic mike connected through an input transformer to an amplifier tube's grid. The mike is rated at -60 dbm power output at one dyne/cm². It has a rated output impedance of 50 ohms. Table C gives us the correction factor for converting the decibel power output to decibel voltage output at 50 ohms. The correction factor is -13, so the voltage level across 50 ohms at the output terminals of the mike is -73 dbv. Table C also gives us the correction factor to find the voltage output as it exists across 40,000 ohms. This correction factor is +16 db, so the output voltage at 40,000 ohms is -60 +16 or -44 dbv. This is the voltage level at the control grid of the amplifier, which is at a 40,000-ohm

TABLE C

Z	25 Ω	50 Ω	150 Ω	250 Ω	600 Ω	25,000 Ω	40,000 Ω
C.F.	-16 db	-13 db	-8 db	-6 db	-2 db	+14 db	+16 db

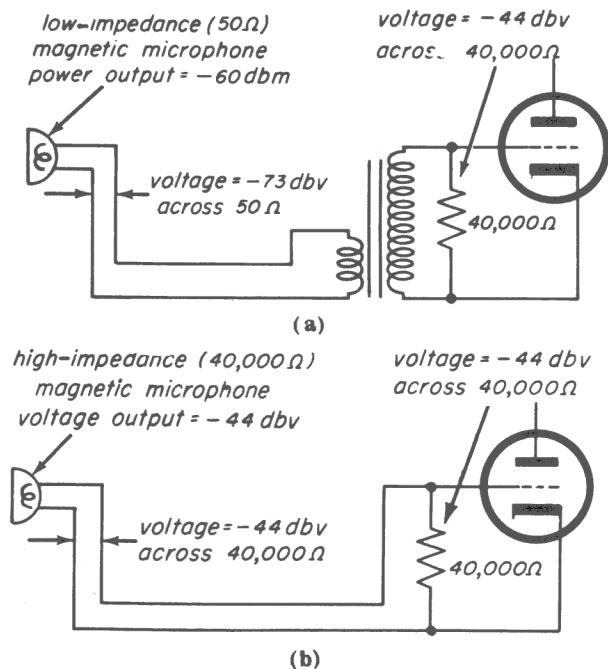


Fig. 26-3

impedance level. Figure 26-3b shows a high-impedance magnetic mike connected directly (no transformer) to an amplifier grid which is also at a 40,000-ohm impedance level. If the second mike has a high-impedance grid rating of -44 dbv at one dyne cm^2 , it has the same output as the first (low impedance) mike.

Crystal mikes are rated according to the decibel voltage level at their output terminals with no load resistance connected (ratings A and B of Table A). These are not true (power) decibels, and cannot be converted to any of the magnetic mike ratings. The actual voltage output is somewhat lower when a load resistor of proper value to insure adequate frequency response is connected. The proper value is usually specified by the microphone manufacturer, although it is satisfactory for practical purposes to connect crystal mikes to any amplifier high-impedance microphone input terminal. The impedance of such terminals is approximately correct for crystal mikes.

To convert rating A to B, add + 20 db.

To convert rating B to A, add -20 db.

The high impedance grid voltage rating (D) for magnetic microphones is the one that most nearly corresponds to the crystal

microphone rating. It corresponds to rating A because both A and D assume a sound input of dyne/ cm^2 and both give the voltage at the amplifier grid. (Crystal mikes are connected directly to the grid with no transformer intervening.) The ratings do not correspond exactly because the voltage output of magnetic mikes depends upon the impedance level and that of the crystal mike does not. However, based upon the assumption that crystal-microphone ratings can be converted to rating D, we can construct a table of correction factors (Table D) for converting all the ratings listed in Table A to rating D. With Table E, the output ratings of any two mikes can be compared regardless of the kinds of microphone or rating involved.

Table E lists several kinds of microphones and the range of outputs that can be expected from each kind. The range of output for each is given several times, once in each appropriate system. Notice that all have a rating in System D. The purpose of this table is to show at a glance the relationship between the various rating systems and to convey some notion of the output capabilities of the various kinds of microphones.

Thus far we have not mentioned rating C of Table A, which calls for output to be stated in volume units. Actually, rating C is not considered a microphone rating system; but it is sometimes convenient to measure mike output with a vu meter (see Theory Lesson 26), so the vu rating is included here to show how it relates to other rating systems.

Although ratings A and B are used primarily for crystal microphones, they are sometimes applied to high-quality magnetic microphones as well. That is, these high-quality magnetic microphones are rated in terms of decibel voltage output with no load resistor connected (open circuit). These are usually low-impedance microphones, intended to be operated into a step-up transformer with no load resistor (grid resistor) on the secondary winding. The power output in dbm and the rated impedance are usually given along with the open-circuit voltage rating. When a magnetic microphone is operated into an open circuit, it delivers about twice as much voltage (6 decibels of voltage more) as when

TABLE D

To Convert	Add
A to D (crystal)*	0 db
B to D (crystal)*	-20 db
C to D	- 2 db
E to D	+ 16 db
F to D	- 4 db
G to D	+ 24 db
H to D	+ 4 db
J to D	+ 90 db

*Conversion from A to D and B to D is possible only when ratings A and B are applied to crystal microphones. Ratings A and B are occasionally applied to magnetic microphones, but in this application they are not directly convertible to rating D. When magnetic microphones are rated with systems A or B, a further rating in system E or F is usually included. See text for explanations of magnetic microphone rating in systems A and B.

it is terminated in its rated impedance. A comparison of the microphone's power rating with its open circuit rating reveals exactly how much more the voltage is with the mike unterminated than it would be if it were terminated. Microphones of this kind are used in radio and television broadcasting. When a microphone is designed to operate open-circuited with proper frequency response and no distortion, it is possible that its performance will suffer if it is terminated.

The power rating in dbm (rating E or F of Table A) is called an effective power-output rating. The microphone delivers about 6 db more voltage to an amplifier than the dbm rating indicates (about 6 db more than the result of converting dbm to dbv with Table C) because magnetic mikes are usually operated into a load resistor (grid resistor) that is so large that the load can be considered an open circuit.

But when the db gain of the amplifier is added to the dbm mike output, the correct amplifier output in dbm results. This is because the standard system of measuring the gain of amplifiers takes the discrepancy into account. Because the microphone is open circuited, it actually delivers no power, only voltage. Connected to the power amplifier, however, it causes a power output from the amplifier. If the power gain of the amplifier is subtracted from the output of the amplifier, the effective power of the mike is obtained. The power output of the mike is called *effective* because it actually does not exist. The effective power output corresponds to the actual power output in dbm that the mike would deliver if it were terminated in its rated impedance (ratings E and F).

Overload. It is possible to overload a mike by subjecting it to an excessively loud sound input. When a microphone is subjected to a louder sound input than it is designed to handle, distorted output results. Microphones that have a diaphragm mechanism

TABLE E

RATING	A	B	D	E	F	G	H	J
Microphone	0 db = 1v 1 dyne/cm ² (dbv)	0 db = 1v 10 dyne/cm ² (dbv)	0 db = 1v $Z = 40,000$ 1 dyne/cm ² (dbv)	0 db = 1mw 1 dyne/cm ² (dbm)	0 db = 1mw 10 dyne/cm ² (dbm)	0 db = .6mw 1 dyne/cm ² (dbm)	0 db = 6mw 10 dyne/cm ² (dbm)	0 db = 1mw 0.0002 dyne/cm ² (db)
Carbon (single button)	-50	-30	-23	-39	-19	-47	-27	-113
Crystal (sound cell)	-54 to -76	-34 to -56	-54 to -76	-	-	-	-	-
Crystal (diaphragm)	-46 to -65	-26 to -45	-46 to -65	-	-	-	-	-
Dynamic	-	-	-49 to -70	-65 to -86	-45 to -66	-73 to -94	-53 to -74	-139 to -160
Velocity	-	-	-58 to -67	-74 to -83	-54 to -63	-82 to -91	-62 to -71	-148 to -157

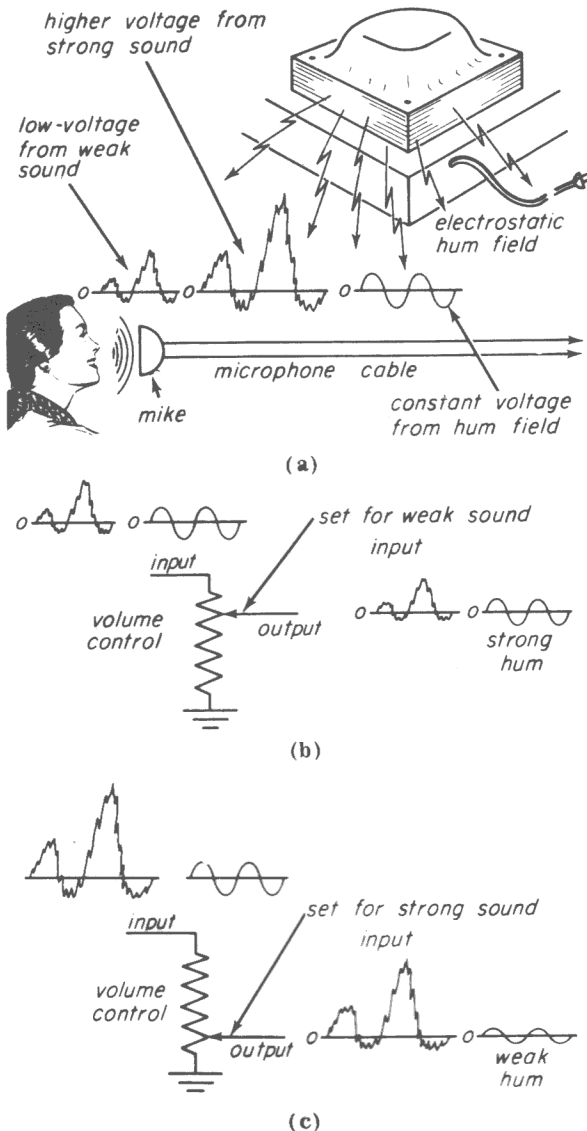


Fig. 26-4

are easier to overload than other kinds. Such mikes can produce undistorted output only for loudnesses that cause the diaphragm to vibrate over a distance less than what the free play of the diaphragm can handle. When the diaphragm is forced to the limit of the free play allowed by its suspension, further movement is checked; further movement does not exactly follow the sound pressure producing it.

26-2. PRACTICAL MICROPHONE CABLES

Shielding. Practical microphone cables are shielded against stray electrostatic hum and noise pickup. The shielding is necessary even for low-impedance cables, even though low-impedance cables are least susceptible to stray pickup. Microphone cables

are subject to electrostatic pickup because (besides the reasons given in our discussion of impedance) the voltage level of the sound signal on the cable is low. Low-level signals of any kind are subject to interference from stray signals (noise and hum). Let us consider why this is so, and how shielding helps prevent stray electrostatic pickup.

Suppose we have a microphone cable that is picking up hum from a radio chassis (Fig. 26-4). As long as we do not alter the relative positions of chassis and cable and do not alter the length of cable, the amount of hum pickup will remain at constant voltage. But the sound signal voltage is not constant. It varies with the loudness of the sound. Hum and signal voltages combine on the cable as in *a*. They are applied to a volume control together. When the volume control is set high for weak sounds as in *b*, the hum voltage comes out strong. When the volume control is set low for strong sounds as in *c*, the hum comes out weak.

So it is the relative amplitude of hum and signal voltage that determines whether or not the hum will be heard. Since even the loudest sound produces only a small output voltage from the microphone (the output signal is said to be at a low level), the amount of hum voltage picked up must be kept very, very small if the hum is not to be heard.

Shielding keeps out hum and noise voltage by covering the cable with a short circuit. This can be understood with the aid of Fig. 26-5. An electric power generator produces a 60-cycle voltage at 120 volts with respect to earth. Two microphone

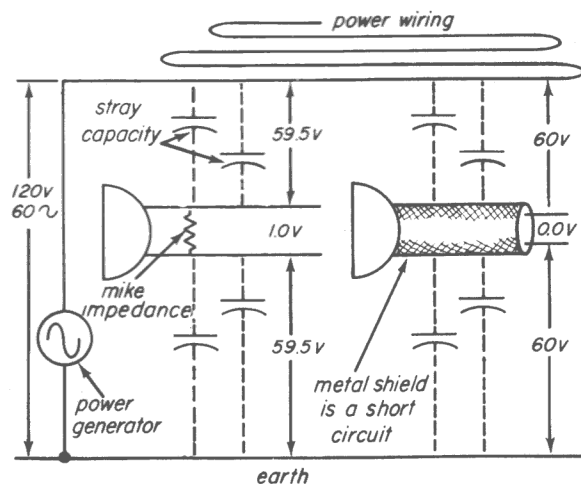


Fig. 26-5

cables are electrostatically connected (by stray capacity) between the 120 volt power wiring and earth. The 120 volts divide between the stray capacity and the impedance of the unshielded mike cable so that one volt at 60 cycles (hum) is across the impedance of the cable (the mike output impedance). No such voltage can develop across the shielded cable because the shield is a short circuit (zero impedance). Instead, all the hum voltage is across the stray capacity where it can do no harm. The shields must completely cover all the microphone wiring without a break. The shield must be electrically connected to the microphone case and to the amplifier chassis.

Practical Cables. Two kinds of shielded microphone cables are in use (Fig. 26-6) — the single-conductor kind *a* and the two-conductor kind *b*. Two leads must connect microphone to amplifier. So when the single conductor is employed, the shield acts as one lead. Since the shield must be connected to chassis, single-conductor cable is usable only with amplifier input circuits that return to chassis (Fig. 27-7a). High-impedance amplifier input circuits return to chassis as Fig. 26-7a shows. It is advantageous to use single conductor cable with high-impedance input circuits (to minimize signal loss in the cable) because the stray capacity of the single conductor arrangement is generally lower than the stray capacity of two conductor

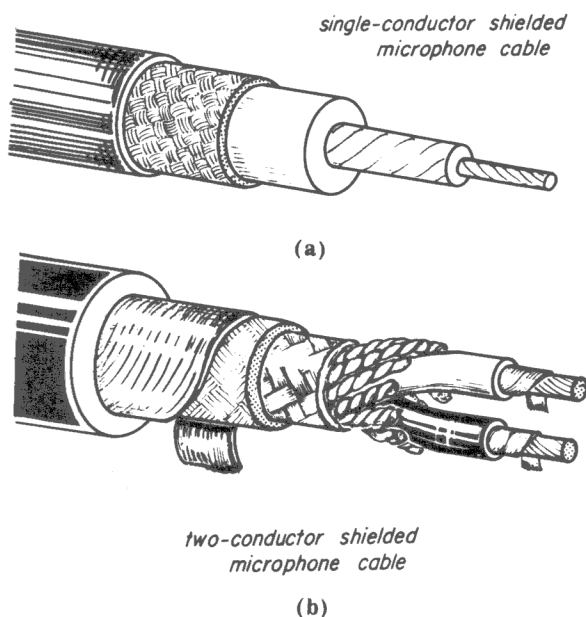


Fig. 26-6

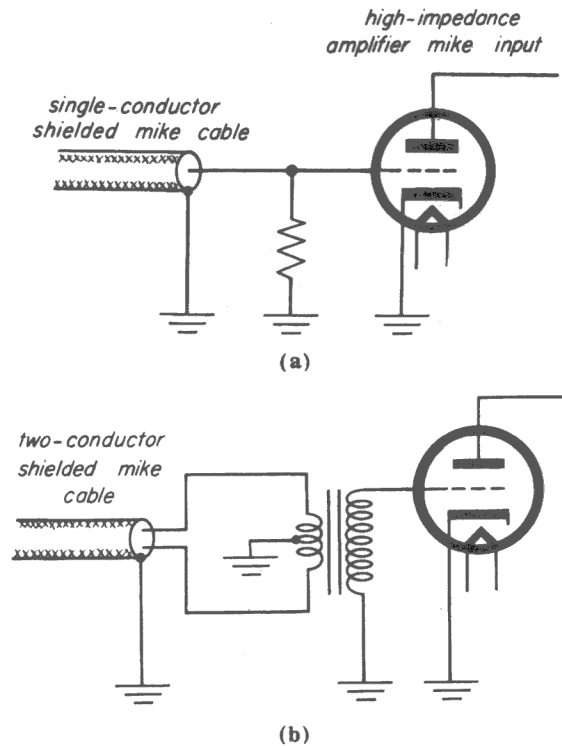


Fig. 26-7

cables. The latter are most used with a balanced low-impedance transformer input to the amplifier as shown in *b*. Low stray capacity is not so important at low impedance, and the two-wire arrangement affords more effective shielding action.

Manufacturers rate microphone cable in terms of stray capacity per foot-length of cable. A typical rating for a good single conductor cable is $33 \mu\text{f}/\text{ft}$.

Figure 26-8 shows some connectors (sockets and plugs) that are used with microphone cable. Phone jacks (sockets) and phone plugs, shown in *a*, are used with single conductor cable. So are the so-called microphone connectors, shown in *b*. With the mike connectors, the center conductor of two cable ends make connection through the pressure contact of two lumps of solder. Each lump fastens the center conductor to the center terminal of one part of the connector — one in the socket and one in the plug. A two-conductor connector is shown at *c*. The connectors are designed to insure that shielding completely covers the wiring.

A precaution necessary when choosing a phone plug for use with a microphone illustrates how important complete shielding can

be. Two kinds of phone plugs are available. The handle part of one kind is plastic, that of the other is metal. The plastic kind works satisfactorily with earphones and other audio equipment operating at a high signal-voltage

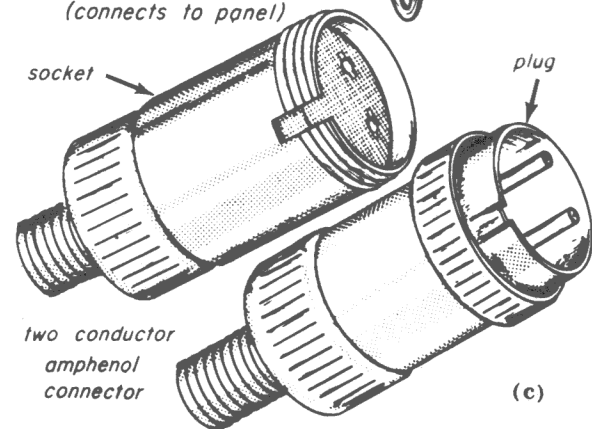
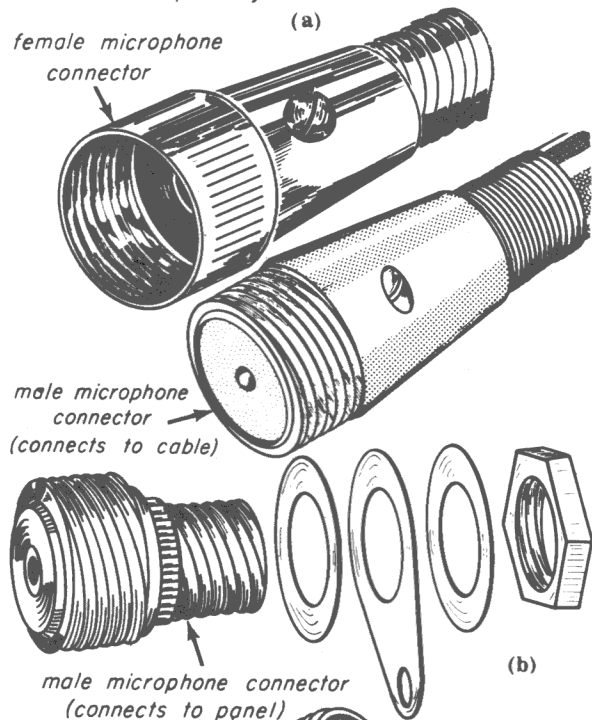
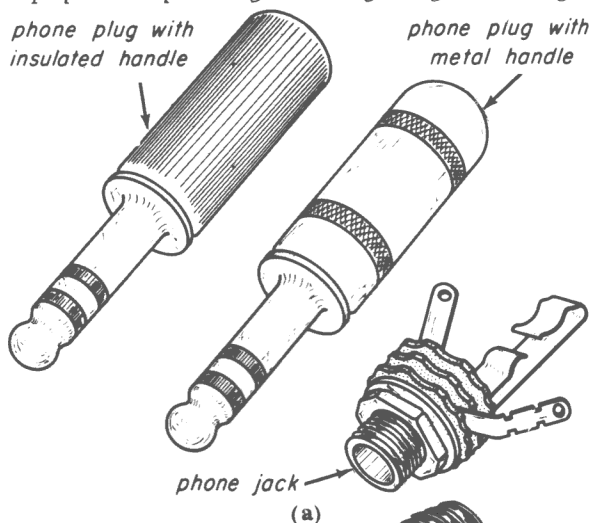


Fig. 26-8

level but not with microphones. The lack of shielding over the small length of cable covered by the plastic handle is enough to introduce annoying hum into the sound signal coming from a microphone. It is necessary to choose only metal-handled phone plugs for use with microphones.

Note. Microphone servicing is largely a matter of maintaining proper continuity and adequate shielding in the connecting cables and plugs, since the mike itself cannot usually be repaired successfully without factory equipment.

26-3. SERVICING LOUDSPEAKERS

We will limit our discussion to the testing and repair of dynamic loudspeakers because this is the only kind in general use at present. Dynamic loudspeaker defects can be divided into three categories:

1. Trouble with the voice coil.
2. Trouble with the field magnet.
3. Trouble with the cone.

In all cases of trouble with the speaker, you can either repair the speaker or replace it with a new one. In earlier days of radio, speakers were more expensive than they are today. Also, they were made in a way to permit complete disassembly (screw fasteners were used instead of welds, etc.) So in earlier days, it was the practice to repair speakers. Today, speakers are more often replaced than repaired. However, if you know how to repair speakers, you will be helped to recognize a defective speaker.

Voice-Coil Troubles. Voice coils can open-circuit and short-circuit. An open-circuited voice coil produces no sound. A short-circuited voice coil can produce either no sound or weak sound, depending upon whether the coil is completely or partly short circuited.

An open-circuited voice coil is shown in Fig. 26-9. We know that an open circuit is revealed by a high-resistance ohmmeter reading. But the ohmmeter shown connected to the terminals of the open voice coil in Fig. 26-9a indicates a low resistance; the meter

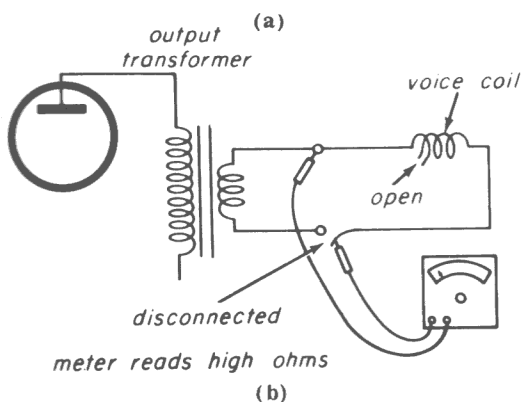
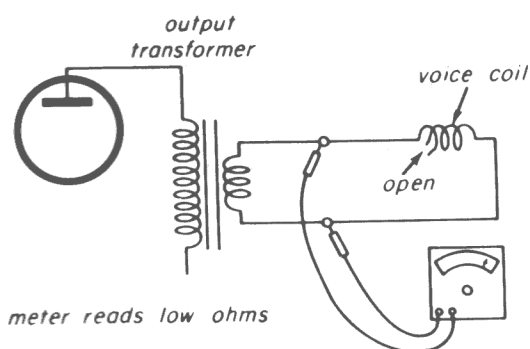


Fig. 26-9

reads the low resistance of the output-transformer secondary even though the voice coil is opened. Figure 26-9b shows the proper way to test a voice coil for continuity. One voice-coil lead must first be disconnected from the output-transformer secondary winding.

The total resistance of a voice coil is so low that it is difficult to read the difference in resistance between a perfectly good voice coil and one with several turns shorted out. It is best to test for voice-coil shorts by temporarily substituting a good speaker. But after this has been done, and the original speaker is found defective, the actual trouble may be something other than a shorted voice coil. Once trouble has been localized to the speaker, by substitution, there are two ways to proceed further. One way is to replace the speaker. Of course when this way is followed it is not necessary to know exactly what part of the defective speaker is at fault. The second way is to repair the defective speaker.

One of the possible speaker faults to be considered is a shorted voice coil. Shorted voice coils can sometimes be found by visual inspection. In fact, this would always be possible if the coil did not extend between the

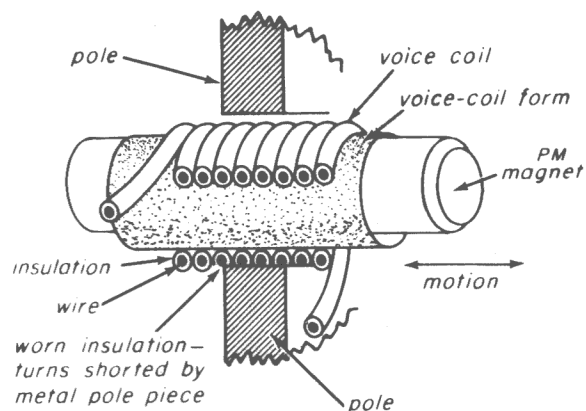


Fig. 26-10

poles of the field magnet, where it is partially hidden from view. The voice coil is not a many-layer coil. The turns are visible unless the coil itself is not accessible.

The commonest way in which voice coils short is illustrated in Fig. 26-10. Here the voice coil is in a slightly off-center position between the field-magnet pole pieces. Insulation wears off the wire of the coil, exposing the copper—and the metal pole piece touches the bare copper of several turns of the coil, shorting them out. This kind of short is usually intermittent. So, one way to detect it is to push the coil against the pole with your finger while listening for intermittent stoppages in the sound proceeding from the speaker.

Trouble with the Field Magnet. Permanent magnet speaker fields are hardly ever a cause of trouble. Electromagnetic field coils open-circuit, short between turns, and short to ground (speaker frame). An open field coil usually results in *no* B+ voltage, because the open field coil, which is usually a power-supply filter choke, opens the B+ circuit. Here is what to look for and do in localizing an open field coil:

1. If the radio produces no sound, no hum, and no hiss but the tubes are lighted, the field coil may be open.
2. Check B+ with a voltmeter. If there is zero voltage, check the field coil for continuity with an ohmmeter.
3. If the ohmmeter shows an open circuit, the field coil is defective.

Shorts between turns of the coil do not produce *no sound*. The sound volume decreases slightly and hum may rise to an objectionable volume level because the shorted field, acting as a power-supply filter choke, is no longer fully filtering B+. Shorted turns cannot readily be detected with an ohmmeter. The best localizing procedure is to substitute a new speaker.

A short from the speaker field to ground is a short from B+ to ground. This trouble usually causes the house power fuse to blow out. If the fuse is a large one, the receiver rectifier tube may blow out. A short to ground in the field coil can be detected with an ohmmeter. Disconnect the field leads from the power-supply filter wiring and measure resistance from one of these leads to chassis. The resistance should be infinite. If not, there is a short. Speakers with defective field coils are usually replaced. However, sometimes a new field coil can be installed in the original speaker.

Trouble with the Cone. The cone suffers mechanical damage. It may rip. It may become unglued from the frame. It may even be eaten away by mice. This is not a joke. Cones are occasionally completely eaten away by rodents. The rodents use the cone material for building their nests. (The result is no sound.) Torn and warped cones cause an effect called *speaker rattle*—a garbling of the sound at all but very low volumes along with strong random vibration of the cone. The effect sounds like the distortion that results from defects in the audio amplifier. To make sure the speaker is at fault, substitute a new one. A warped cone can cause the voice coil (which is attached to the cone) to seat off center between the poles of the field magnet. This can lead to short-circuiting of some of the turns of the voice coil, as previously described.

A torn cone is worse than a cone with a hole in it. A torn cone rattles because the two edges of the tear slap together as the cone vibrates to the rhythm of the sound being produced. A clean-cut hole in the cone does not cause noticeable distortion because the edges of the hole are not in position to touch together. Of course, if the hole is large enough, sound volume is reduced.

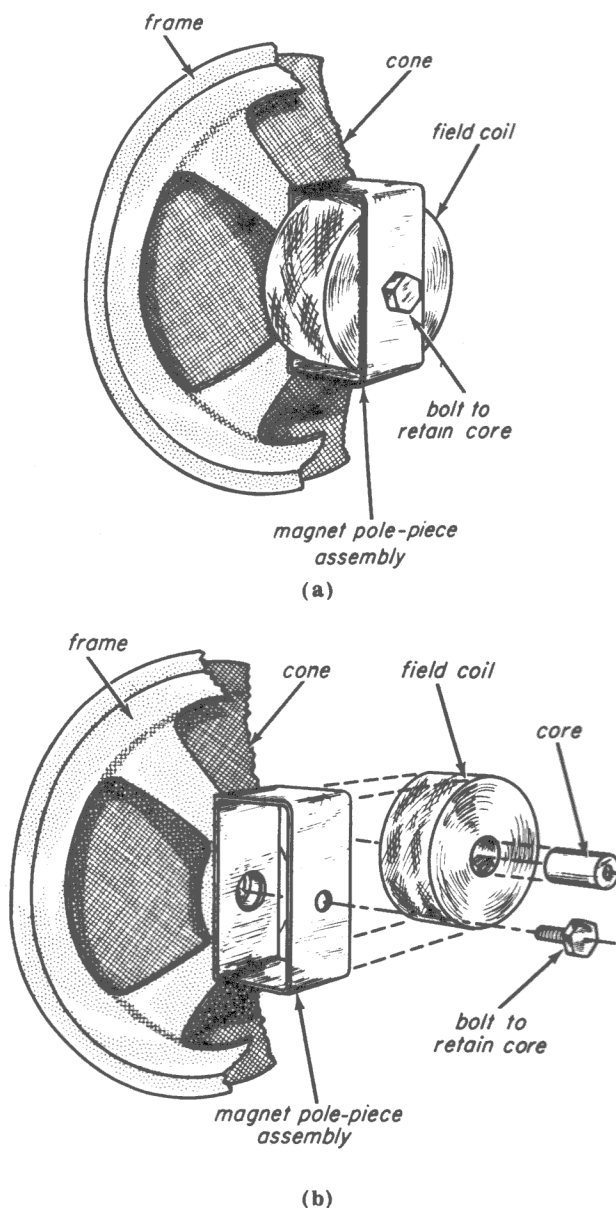


Fig. 26-11

Repair of Dynamic Speakers. Not all dynamic speakers can be repaired. Some cannot be disassembled because of the way they are fastened together. Others can be disassembled, but spare parts to fit may not be available. When a speaker is repaired, exact replacement parts must be used.

Figure 26-11 shows replacement of a field coil in one kind of speaker construction. At *a*, the speaker is shown as it appears before disassembly. To remove the field coil, the core retaining bolt is first removed. Then coil and core are pushed sideways out of the magnetic pole-piece assembly; the core is removed from the coil to be reused with

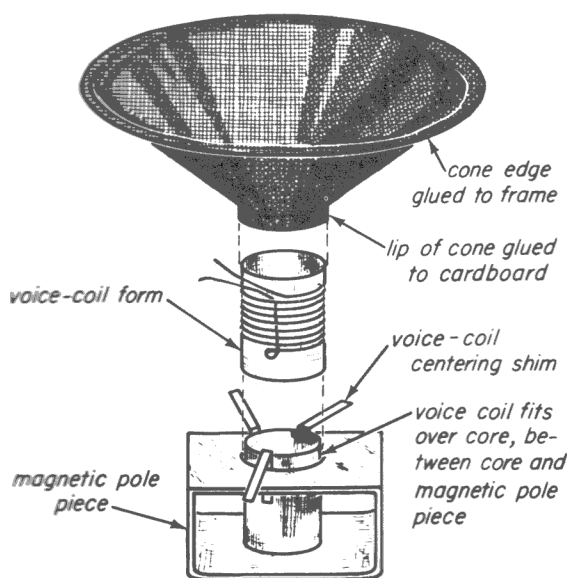


Fig. 26-12

the new field coil. Figure 26-11b shows the speaker disassembled. Sometimes the cone is held in place by a press fit. There are also other kinds of construction.

A permanent-magnet speaker is shown in Fig. 26-12. The voice-coil cone assembly is basically the same in either PM or FM speakers. The voice coil and cone can usually be replaced separately. However, both must be removed from the speaker frame preparatory to replacing either. The procedure to be followed when removing them is evident from the drawing (Fig. 26-12). It is easy to remove a voice coil and cone from the frame of a speaker. Installing a new cone and coil can be irksome because it is necessary to precisely center the voice coil in the small circle of space between the core and the magnetic pole piece. Centering shims are used to center the coil. The shims are paper-thin pieces of metal. Three shims are wedged between the voice coil and the circular hole in the pole piece to hold the coil in center position while glue dries, binding the one edge to the speaker rim. Care must be exercised (when wedging the coil in place) to make sure that the coil form does not touch the core at any point along its entire length.

Many speakers, especially large ones, have the cone supported at the voice-coil end as well as at the rim. Sometimes the anchoring of the suspension is adjustable. This adjustment permits accurate centering

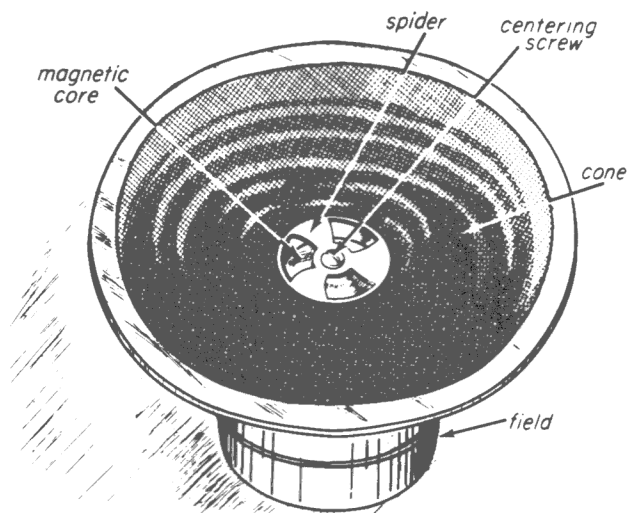


Fig. 26-13

of the voice coil. A typical method of suspension at the voice-coil end of the cone is the spider method illustrated in Fig. 26-13. The spider is a thin springy disk of metal that looks something like a spider web. The rim of the disk is glued to the cone. The center of the disk is screwed to the core. The hole in the spider through which the mounting screw passes is larger than the diameter of the screw so that the voice coil can be moved in any direction for centering; the screw can be tightened down to hold spider and coil in the desired position. A procedure for making the adjustment is as follows:

1. Rest the speaker on a level flat surface, cone up.
2. Loosen the screw.
3. Apply a sixty-cycle signal to the speaker.
4. As the cone vibrates to the sixty-cycle (hum) tone, the voice coil will center itself.
5. Tighten the screw while the speaker hums.

26-4. ADDING AN EXTRA LOUDSPEAKER

The simplest way to wire an additional loudspeaker to a radio is shown in the schematic, Fig. 26-14. The built-in speaker shown in Fig. 26-14 is the dynamic kind, as is always the case in practice. The speaker to be added should be the permanent-magnet dy-

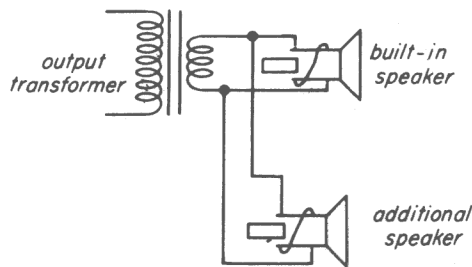


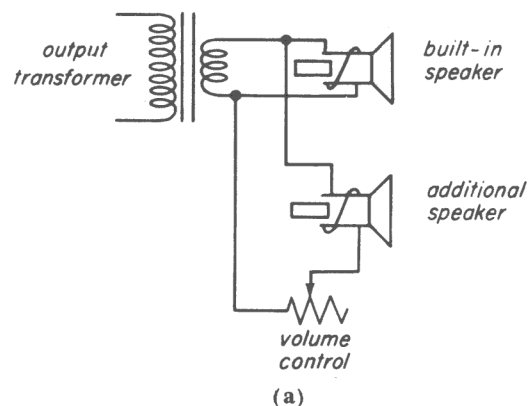
Fig. 26-14

dynamic kind so that no field current need be furnished. As you see, the additional speaker is simply connected in parallel with the built-in speaker. This arrangement reduces the plate-load resistance reflected back to the plate of the output tube. An impedance mismatch is introduced when the additional speaker is connected. The resulting distortion is usually tolerable, however, except in high-fidelity applications. (The mismatch when more than one speaker is added is not tolerable. We will study methods of connecting many speakers without causing mismatch when we discuss public address systems in later lessons. The expense entailed in matching additional speakers is not warranted for the application under discussion here).

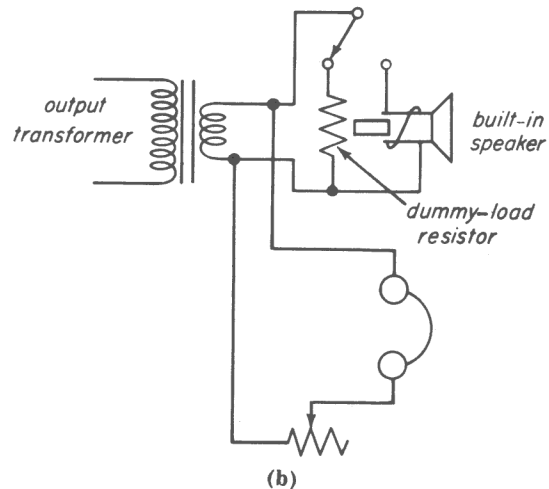
When a speaker is added in shunt with a built-in speaker as shown in Fig. 26-14, the relative impedance of the two determines how output power from the amplifier will divide between them. If the added speaker has the same voice-coil impedance as the built-in speaker, power divides equally. But, for example, if the built-in speaker has a 3-ohm voice coil while the added speaker has a 6-ohm voice coil, then the added speaker gets half as much power as does the built-in speaker. This effect can be used to regulate the relative loudness of the added speaker. The higher the voice-coil impedance of the added speaker, the lower its loudness compared to the built-in speaker. Of course, neither speaker will be as loud as one alone.

Sometimes it is necessary to control the volume of the additional speaker separately. The simplest arrangement for this purpose is shown in the schematic (Fig. 26-15a). A variable resistor is connected in series with the added speaker to control its volume. This arrangement has two disadvantages:

1. It is not possible to shut off the added speaker completely.



(a)



(b)

Fig. 26-15

2. When the resistor is adjusted to decrease the volume of the additional speaker, that of the built-in speaker increases.

With the arrangement shown, the volume of the controlled speaker is reduced by increasing the resistance of the control so that more power develops across the control resistor and less across the controlled speaker. However, no matter how much the resistance of the control is increased, some power develops in the controlled speaker; some volume remains. As the resistance of the control is increased, the total load resistance in shunt with the built-in speaker is increased. Less power is drawn away from the built-in speaker and its volume increases.

For these reasons, the arrangement of Fig. 26-15a is not satisfactory for controlling the volume of an added speaker. Nevertheless, the arrangement is satisfactory for controlling the volume of added earphones. A schematic showing how magnetic phones may be connected in shunt with a dynamic loudspeaker, the volume of the phones con-

trolled, and the speaker controlled with an on-off switch is shown in Fig. 26-15b. Since the impedance of the phones is high (about two thousand ohms), they take but little power away from the speaker. When the variable resistance is set for minimum volume in the phones, the total resistance in shunt with the speaker is even higher. Less power is drawn away from the speaker. But the difference between the most and least power delivered to the speaker is not great enough to cause a noticeable change in speaker volume. The effect upon the speaker of the earphone volume control is not great enough to be a disadvantage.

The speaker on-off switch makes it possible to turn off the speaker while the phones are in use. The switch operates to connect a resistor in place of the speaker when the speaker is disconnected. The value of the resistor should equal the rated impedance of the speaker voice coil. The resistor serves to maintain the proper load resistance for the amplifier output tube when the speaker is disconnected. This prevents distortion that would result if the impedance of the speaker (several ohms) were replaced with the impedance of the phones (two-thousand ohms). Also, since the resistor draws the same amount of power as does the speaker, no change in volume is heard in the phones when the switch is operated.

Figure 26-16 shows a volume-control circuit that is suitable for controlling the volume of an added speaker. The control consists of two variable resistors, the moving contacts of which operate together. Con-

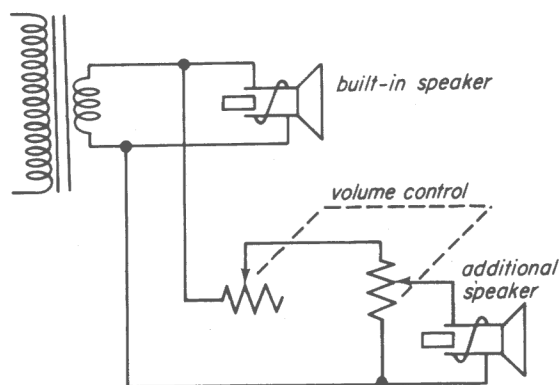


Fig. 26-16

trols of this kind are manufactured for the specific purpose of controlling the volume of loudspeakers and may be purchased from radio-parts wholesalers. One of the variable resistors of the control is connected in series with the speaker to be controlled; the other resistor of the control is connected in parallel with the speaker to be controlled. As the handle of the control is turned to decrease volume, the series resistance increases and, at the same time, the parallel resistance decreases. The total resistance in shunt with the built-in speaker remains the same at all settings of the control. So, the volume of the built-in speaker is not affected by operation of the control. Also, when the control is set at minimum volume, the resistance in parallel with the speaker is zero ohms; the added speaker is shorted out and shut off completely. The arrangement of Fig. 26-16 divides the sound-power output from the amplifier in three parts — one part to the built-in speaker, one part to the control, and one part to the additional speaker. The maximum volume obtainable from either speaker is reduced accordingly.